The Relationship between gully characteristics and sediment production in the Northeast of Iran, Golestan province

Soufi, M.[1] – Isaie, H.[2]

[1]Assistant Professor and Research Scientist, PhD, Fars Research Center for Agriculture and Natural Resources, Shiraz, Iran, P.O.Box: 71345-1756, Tel.0711-7209332, Fax:0711-7205107, E-mail: soufi@farsagres.ir
[2]Golestan research center for Agriculture and Natural Resources, Junior Research Scientist, Soil conservation and watershed management dept.

1. Abstract

Gully erosion has occupied more than 600 sq.km in Golestan province, the northeast of Iran. For classification and prioritization of the gullies regarding sediment production, different indices were used by researchers.

In this research the gullies with an area larger than 5 sq.km were determined using historical evidence and field survey. Climatic classification of the regions affected by gully erosion was performed by De-marton's method. From each climatic zone, two regions and in each region 3 representative gullies were selected and morphoclimatic characteristics and soil properties were measured. The volume of gully erosion was calculated by summation of the partial volumes. Partial volume was calculated by multiplying cross sectional area by partial gully length. The correlation between the volume of gully erosion and form factor(W/D) and W/L ratio was determined.

This results of this research indicate that intensive gully erosion was formed in two watersheds of six existing watersheds in Golestan province. The Atrak and the Gorgan watersheds with Loess soil are prone to intensive gully erosion. Gully erosion covered more than 600 km^2 in this province. The gullies are distributed in moderate and cold arid and semi-arid climatic zones. Soil texture is silt loam. The gullies in arid climate have larger W/D than those in semi-arid climates. Regions with silt content higher than 60% experienced the highest top width in this part of I.R.Iran. Statistical analysis with stepwise method indicated that variation of the gully length interpreted 92% of variation in the volume of erosion. R-square increased with adding gully depth but there was no better R-square by adding top width parameter. We recommend using the length of the gully to estimate the volume of gully erosion. Especially this parameter could be measured on the historical evidence such as aerial photos.

Keywords: form factor, gully, sediment production, Iran, classification, prioritization, climate

2. Introduction

Gully erosion has attracted more attention due to more sediment production and limited research recent years (Poesen et al. 1988, 2003). Gully is an erosion channel which can not be obliterated by normal operation tillage (Soil science society of America, 2001) and its cross sectional area is larger than 1 ft^2 (Poesen et al. 2003). For prioritization of regions with gully erosion in view point of control, presenting indices and relationship to estimate sediment production is necessary. The length of gully is a key parameter to determine the volume of gully erosion for EGEM (Nachtergaele et al., 2001b). As there is a strong correlation between the length and volume of the gully (Cheng et al., 2007), it is suggested that gully length is a significant and useful index to estimate the volume of gully erosion especially in large scale surveying of gully erosion because it is easier to measure the gully length from historical evidence such as aerial photos or remotely sensed images (Cheng et al., 2007; Hughes et al., 2001).

US-SCS (1966) by using w/d ratio of erosional channels found that in the cohesive soils, the width of the gullies is 3 times of their depth while in non-cohesive soil, this ratio is 1.75 times (Relationship 1 and 2).

D=0.34W   cohesive soil (1)
D=0.57W   non-cohesive soil (2)

Radoane et al. (1990) presented a linear relationship between w/d and gully length (relationship 3).

$$\frac{W}{D} = 1.287 + 0.00199\,L \qquad\qquad R^2 = 0.39 \quad (3)$$

Vandekerckhove et al. (2000) in a research in the southeast of Spain found that the volume of gully erosion (V) has a positive correlation with w/d ratio ($R^2 = 0.436$ and $P = 0.0004$) and a negative correlation with W/L ratio ($R^2 = -0.536$ and $P = 0.0001$). The results of this research revealed that gully widening had a more important role than gully deepening in the Lisbon, the southeast of Spain. Nachtergaele et al. (2001a & 2002) found a relationship between the volume and length of the gully in 80% of samples. They found that gully length is an estimator of gully volume. In 91% of the gullies that formed in one event, gully

volume could be estimated by gully length correctively. Also, correct estimation of gully length would estimate the gully cross section correctly in 35% of the samples. Nachtergaele et al. (2001b) in their research in Portugale found a power relationship between gully volume and gully length (equation 4).

$$V = 0.05L^{1.27} \qquad\qquad (4)$$

In which V is gully volume (m^3), L is gully length (m), a and b are 0.05 and 1.27 in Portugal and 0.1839 and -0.2385, respectively in loess plateu In China. Capra et al. (2005) in the model calibration for estimation of gully volume in Sicily, Italia, found the relationship number 5 between gully volume and length. To find higher R square, they used stepwise method in SPSS software to indicate the influence of several indices such as , Catchment area, length of catchments, Catchment gradient, Gully length, Gully slope, 24 hours rainfall, third day rainfall, threshold rainfall equal to 37 mm on the volume of gully erosion. The final equation (6) indicated that R square was a little better than equation 5 (R^2=0.72) but the most important factor is the length of gully to predict the volume of gully erosion.

$$V = 0.0082L^{1.416} \qquad\qquad R^2 = 0.64 \qquad\qquad (5)$$
$$V = 10^{-4.91} L^{1.557} 24 - hRa \inf all^{1.327} \qquad R^2 = 0.72 \qquad\qquad (6)$$

Zhang et al. (2007) presented a power relationship between the volume and the length of gullies in the cultivated catchments of black soil region , the northeast of China as follows:

$$V = 0.015L^{1.429} \qquad\qquad (R^2 = 0.67, P < 0.05) \quad (7)$$

3. Methods

This research was carried out in Golestan province, the northeast of IR. Iran. The region with gully erosion area larger than 5 km^2 was determined using historical and anecdotal and evidence and field survey. The climate of gully regions was determined using Demarton's classification. Six representative gullies were selected to measure their morphometric and soil characteristics in each climate zone. Measurements of top and bottom width and depth were done in the headcut, 25, 50 and 75% of gully length from headcuts. Soil samples were taken from those points. View plan, headcut plan and long profiles of the gullies were surveyed using theodolit. The volume of gully erosion was estimated using partial volumes. The partial volume was caculated by multiplying partial area by the interval between sections. The relationship between the volume of gully erosion as dependent variable and morphometric and soil characteristies of gullies as independent variables was considered using stepwise method in SPSS software.

4. Results

Two watersheds from six watersheds experienced gully erosion in Golestan province. Gully erosion occupied more than 600 km^2. It developed in four climates including mild desertic arid, cold desertic arid, cold semiarid and mild semiarid. Average annual rainfall was between 200 and 471 mm. The length of represented gullies were between 50 and 110 meters. The depth of the gullies was between 0.7 to 9.5 meters. The top width of the gullies varied between 3.7 and 27.5 meters. The bottom width of the gullies was between 1 and 10.5 meters. The volume of gully erosion was calculated between 133 (Alagol region) and 23000 m^3 (Maravehtapeh region). The result of this research reveals that a liner and positive relationship exits between the top width and depth of gully erosion although its R^2 is relatively lower (Table 1). Regions with more clay experienced a lower top width and regions with silt more than 60% indicated the largest top width. The relationship between the top width and depth of gullies is significant in the 5% significance level. This is similar to the relationship (2) presented by US-SCS (1966). This relationship implies that gully widening is happening in Golestan province. In other words, the risk of land degradation (rangeland and rain fed farms) is higher in these regions. Also, there is a linear relationship between W/D ratio and gully length (Table 1). It implies that with increasing one unit in the gully length, 0.66 unit of W/D ratio will be increased.

Table 1 Relationship between morphometric parameters of the Golestan gullies

	standard coefficient	R^2	p
$D = 2.146 + 0.173wt$	0.55	0.26	0.05
$wr/D = 2.27 + 0.006L$	0.66	0.41	0.05

The results of statistical analysis indicated that the volume of gully erosion had positive relationship with length, top and bottom width, depth and form factor and negative one with EC, Ca, SAR, Clay, wb/wt and wt/L . The

volume of gully erosion had a significant correlation with length, top and bottom width (P<0.01) and with from factor, w_t/D (P<0.05).

The simplest linear equation existed between the volume and length of representative gullies. The result indicated that 92% of variation in the volume of gully erosion was interpreted by the length of gullies. In addition to gully length, gully depth increased R^2 to 0.97 but with adding gully top width, Wt, to the relationship, R^2 was not increased significantly (Table 2). Considering the power relationship, there exists the following equation as follows.

$$V = 5.64L^{1.24} \qquad\qquad R^2 = 0.52 \qquad P<0.01 \qquad\qquad (8)$$

This relationship in regarding R^2 and exponent is very similar with that presented for ephemeral gullies in the croplands of Sicily, Italy. Also the exponent of the power relationship for gullies in Golestan province is very similar to the one presented for ephemeral gullies in Portugal by Nachtergaele et al. (2001b). The difference between α coefficient in Golestan, 5.64, with 0.0082 in gullies from sicily, Italia, might be related to the different type of gullies. Sicily gullies are ephemeral and small gullies that could be obliterated by normal tillage operations while Golestan gullies were permanent ones and their dimensions were larger than that of the Sicily gullies.

Table 2 Relationship between the volume of gully and it's morphometric characteristics

variable	(β_1)	(β_2)	(β_3)	R^2	P
L	0.932			0.86	0.01
L,D	0.966	0.325		0.97	0.01
L, D, Wt	0.871	0.227	0.159	0.978	0.01

5. Conclusion

In Golestan province, two out of six watersheds experienced gully erosion. Total area that was covered by gully erosion was over 600 km^2. Gully erosion occurred in four climates including mild desertic arid, cold desertic arid, cold and mild semiarid. The results indicated a linear and positive relationship between the top width and depth of gullies although R^2 was lower. This implies that widening is occurring in gullies of Golestan province. Regions with silt content higher than 60% experienced the highest top width in this part of I.R.Iran. Statistical analysis with stepwise method indicated that variation of the gully length interpreted 92% of the variation in the volume of erosion. R^2 was improved by adding the gully depth but there was no better R^2 with adding top width parameter. We recommend using the length of gully to estimate the volume of gully erosion in this province. This parameter could be especially measured on the historical evidence such as aerial photos.

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